Evaluation of Potential Use of Vegetation for Erosion Abatement Along the Great Lakes Shoreline

by
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This study identifies plants with potential, either alone or in combination with structures, to alter the erosion rate along shores of the Great Lakes. Information was obtained from literature, personal interviews, and a field survey. Shoreline plants were identified and evaluated. Thirty-three terrestrial species were found that effectively decreased surface erosion resulting from wind and runoff. No emergent or submergent plants were found to control erosion. While several emergent species may have special use in

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EVALUATION OF POTENTIAL USE OF VEGETATION FOR EROSION ABATEMENT ALONG THE GREAT LAKES SHORELINE

by

V.L. Hall and J.D. Ludwig

I. INTRODUCTION

The present physical characteristics of the Great Lakes shores in the United States resulted from natural changes in the Great Lakes region since the glacial recession and from the man-induced developments of recent years. The shore varies from high clay, shale, and rock bluffs, to lower shores of rock, sandy beach,and marsh. Except where bedrock is already exposed or protective works have been constructed, the shores of the Great Lakes are being altered by water and wind erosion.

Wave erosion is the most severe type of erosion occurring along the open shores of the Great Lakes. Damage from wave erosion has been more pronounced since lake levels have risen, the result of recent increases in rainfall over the Great Lakes basin. The average annual rainfall from 1900 to 1972 for the basin was about 32 inches; since 1964, however, the annual rainfall has been above that 72-year figure (International Great Lakes Levels Board, 1973, 1974).

Surface runoff, the second most prevalent type of erosion along the Great Lakes shores, is most destructive on steep, unprotected slopes. If protection is inadequate, gullies form rapidly. A related problem, seepage, causes slumping, which increases the erosion rate and probability of landslides.

Other agents of lesser concern causing shoreline erosion are freezing and thawing and the action of floating ice. Freezing increases the volume of water and thawing reduces the volume; the expansion-contraction process can move soil or rock sufficiently to cause landslides or rockfalls. In addition to the displacement from freezing, thawing may also cause an unstable layer to form between the ice and substrate, thus increasing the tendency toward bank failure.

Floating ice has a variable effect on shore erosion. Driven ashore by strong winds, it can cause extreme land scouring. On the other hand, ice may move onto shore and form a protective barrier against wave action that would otherwise erode the shore.

Wind erosion, normally a dry-weather phenomenon, occurs around Great Lakes dune areas that are droughty and barren. Wind is especially destructive in dune areas, blowing sand inland. The deposited sand may bury established vegetation and perhaps develop a new dune area.

Erosional problems and damages include loss of land, imperilment to roadways, loss of recreational beach, loss of access to the lakes, and structural damage to dwellings, boathouses, docks, and stairways. Some shoreline conditions along the Great Lakes are difficult to alter to control erosion, particularly in areas where there is no beach or where the water interfaces immediately with steep bluffs. However, there are numerous areas where erosion can be abated by attenuating wave action with mechanical barriers and then using terrestrial and aquatic vegetation to protect the shore against the reduced wave action and against surface runoff.

There are three types of terrestrial plants that can be used to abate erosion: (a) pioneer plants, the species to first become established on new substrates; (b) secondary plants, the species to first invade edaphically stable areas colonized by the pioneer plants; and (c) tertiary plants, the species poorly adapted to dynamic conditions and requiring areas previously stabilized by pioneer and secondary species.

Most species used in terrestrial planting operations are the pioneer type. The pioneer initiates a development sequence (Cowles, 1899; Hack, 1941). It stabilizes the surface, provides lodging for windborne disseminules, shields seedlings from sun and wind, and prepares the way for natural invasion of other plant types (Daubenmire, 1968).

Establishment of hydrophytes (submergent or emergent plants) is very difficult. They are highly restricted by currents and water level fluctuations. Emergent hydrophytes are limited to low-energy shores, where they modify less forceful waves; submergent aquatic plants establish in even more protected areas. The restriction of submergent species to quiet waters limits their phytogeographical distribution, and their vulnerability to strong wave forces prohibits them from naturally colonizing the wave-swept littoral zones of lakes.

The main purpose of this investigation was to determine if terrestrial and hydrophytic plants, either alone or in combination with structures, can be used to attenuate wave energy immediately offshore and to stabilize the areas adjacent to the waterline, thereby reducing the erosion rate along the Great Lakes shores.

II. PROCEDURES

The study was conducted in two phases, a literature search and a field survey. In both parts of the study, the emphasis was on vegetation endemic to the Great Lakes area, because these plants are expected to be well adapted to the present environmental, edaphic, and climatological stresses.

1. Literature Search.

The literature was reviewed for pertinent information on plants

useful for reducing shore erosion. Based on information from these sources, plants were evaluated for their potential adaptability to abate erosion on the Great Lakes shoreline. Plants were classified by their ability to invade and become established as pioneer, secondary, or tertiary species.

Federal and State agencies, universities, and private industries provided topographic maps of the Great Lakes shoreline and several reports related to erosion problems and controls. Interviews were held with personnel knowledgeable about the Great Lakes area or erosion control methods.

During the literature survey, information on use of structures and shoreline modifications was collected and used to form broad guidelines for evaluating how various structural and shoreline modifications might be used with vegetation to decrease erosion rates.

2. Field Survey.

A scorecard fashioned after Parker and Woodhead's (1944) scorecard was developed (Table 1) for evaluating the erosion control potential of plants found at the site. The card was designed to index reproductive potential, density, composition, organic litter accumulation, soil deposition and removal, gully formation, slope angle, and evidence of wave action. The card allowed for evaluation of species to be performed *in situ*. Since the card includes two edaphic categories not applicable to aquatic plants, the investigators weighted the evaluations of the remaining parameters to compensate for the difference. The best expression of each category received the lowest numerical value; plants with an index less than 31 classify as potentially effective erosion abatement species.

Reconnaissance of the Lake Superior shore included the States of Wisconsin and Michigan; Lake Michigan shores were surveyed near Kewaunee, Wisconsin, and from Milwaukee, Wisconsin, to Muskegon, Michigan. The north and south shore of Lake Huron were surveyed. The Lake Erie shoreline from Detroit, Michigan, to Buffalo, New York, was inspected. The Lake Ontario shoreline was surveyed from Youngstown to Rochester, New York, wherever there was access to the lake. Sampling points (Fig. 1) for each of the lakes are located by county, State, and vicinity in Table 2.

Because private ownership along the Lake Michigan shore limited access, the number of survey points there was reduced.

III. FIELD OBSERVATIONS

1. Lake Superior.

Most Wisconsin shores east of Superior to Cornucopia, particularly along the red clay bluffs, are subject to eroding runoff from upland areas, undercutting by wave action, and clay bank sloughing caused by seepage.

Table 1. Scorecard indexing erosion control potential of plant species.

Date ____________
Site Location ____________
Genus ____________
Species ____________
Common Name ____________

PLANT INDICATORS: Based on color, height and volume, compare with moderately protected areas.

Plants robust, with healthy, dark green color and extremely numerous leaves, seed stalks long and numerous, few or no dead plants. Reproduction plentiful in good years 1

Plants as above with long seed stalks. Reproduction sparce except in extremely good years. Occasional spots in the vegetative type in fair or poor condition 3

Plants moderately healthy with moderate length seed stalks 5

Plants weak, may be pale, sickly color. Seed stalks few and extremely short. Seedlings rare with death loss great 7

Plants with new basal or terminal growth and plentiful young plants 1

Plants hedged 2

Plants assume hedged appearance 3

Many plants dead or with numerous dead branches. Inferior species present 5

Density Excellent 1 Good 2 Fair 3 Poor 4

Composition Excellent 1 Good 2 Fair 3 Poor 4

Annual grasses and/or weedy species
Sparce or lacking 0 Abundant 1 Very abundant 2

SOIL INDICATORS:

Organic litter on soil surface between plants

Very abundant 1
Common 2
Scarce 3
None 4

Sand and soil deposition (wind)
No drift 0
Slight drift 1
Moderate drift 3
Heavy drift 5
Excessive drift (blown sand and dunes) 7

Sand and soil removal (water and wind)
All soil layers or horizons intact and well covered with plant debris, no apparent sheet erosion 0

All soil layers intact but soil movement can be detected by occasional miniature alluvial fans, occasional exposed pebbles and rocks 1

Upper soil horizon beginning to break up with numerous miniature alluvial fans, erosional pavement forming from exposed pebbles and rocks 3

Upper soil horizon rapidly being removed, with spots of raw subsoil exposed, erosional pavement developed 5

Upper soil horizon largely removed, erosional pavement excessive, soils generally hard and compact, raw subsoil exposed 7

Gully formation

No gullies 0
Occasional small shallow gullies but well healed with vegetation 1
Occasional shallow gullies 2
Occasional deep gullies 3
Frequent gullies, shallow 5
Frequent deep V- or U- shaped gullies 7

Slope angle

0-20% 1
20-35% 2
35-60% 3
60% and above 4

Evidence of wave action

Normal or below .... 1 Abundant .... 2 Excessive 3

INTERPRETATION OF TOTAL SCORE

Excellent 7-18
Good 19-30
Unsatisfactory or fair 31-42
Poor 43-54

Total Score ________

Other Comments:

(After Parker and Woodhead, 1944)

Figure 1. Locations of sampling points along the Great Lakes.

Table 2. Sampling points along the Great Lakes shoreline.

Sampling Point	County/State	Vicinity
Lake Superior		
1	Bayfield, Wisconsin	West of Fish Creek mouth on State Route 13
2	Bayfield, Wisconsin	2.5 miles west of Port Wing on State Route 13
3	Bayfield, Wisconsin	North of Port Wing and east of lighthouse
4	Bayfield, Wisconsin	Herbster
5	Bayfield, Wisconsin	Cornucopia
6	Marquette, Michigan	Buckroe
7	Marquette, Michigan	32 miles west of Munising on State Route 28
8	Alger, Michigan	11 miles west of Munising on State Route 28
9	Alger, Michigan	Grand Marais State Park
10	Chippewa, Michigan	Whitefish Point
Lake Michigan		
11	Kewaunee, Wisconsin	Kewaunee
12	Lake, Illinois	Illinois Beach State Park
13	Cook, Illinois	Glencoe
14	Cook, Illinois	Kenilworth
15	Porter, Indiana	Porter
16	Berrien, Michigan	New Buffalo
17	Berrien, Michigan	Union Pier
18	Berrien, Michigan	Warren Dunes State Park
19	Berrien, Michigan	St. Joseph
20	Van Buren, Michigan	4.5 miles south of Grand Haven, Van Buren State Park
21	Emmet, Michigan	Cecil Bay
Lake Huron		
22	Mackinac, Michigan	38 miles east of State Route 134, I-75 Interchange on State Route 134
23	Mackinac, Michigan	3.4 miles east of State Route 134, I-75 Interchange on State Route 134
24	Presque Isle, Michigan	6.7 miles northwest of Huron Beach on U.S. 23
25	Presque Isle, Michigan	5.9 miles northwest of Huron Beach on U.S. 23
26	Presque Isle, Michigan	2.8 miles northwest of Huron Beach on U.S. 23
Lake Erie		
27	Monroe, Michigan	Sterling State Park
28	Ottawa, Ohio	Crane Creek State Park
29	Erie, Ohio	2.7 miles west of junction of State Route 60 and State Routes 2 and 6 in Vermilion
30	Erie, Ohio	1 mile west of junction of State Route 60 and State Routes 2 and 6 in Vermilion
31	Lorain, Ohio	2.7 miles west of junction of State Route 611 and 6 in Lorain
32	Lorain, Ohio	0.8 mile west of junction of State Route 6 and 57 in Lorain
33	Cuyahoga, Ohio	Huntington Park, Cleveland
34	Lake, Ohio	Headlands State Beach Park, Fairport Harbor
35	Lake, Ohio	Madison-on-the-Lake
36	Ashtabula, Ohio	Geneva-on-the-Lake
37	Ashtabula, Ohio	Ashtabula
38	Ashtabula, Ohio	Conneaut
39	Erie, Pennsylvania	Presque Isle State Park
40	Erie, Pennsylvania	Freeport Yacht Club junction of State Routes 5 and 89
41	Chautauqua, New York	Ripley
42	Chautauqua, New York	Barcelona
43	Chautauqua, New York	Lake Erie State Park
44	Chautauqua, New York	Dunkirk
45	Erie, New York	Evangola State Park
Lake Ontario		
46	Niagara, New York	Coolidge Beach
47	Niagara, New York	Roosevelt Beach
48	Niagara, New York	Wilson
49	Niagara, New York	Lakeview
50	Orleans, New York	Shadigee
51	Orleans, New York	Lakeside
52	Monroe, New York	Hamlin Beach State Park

Wave action and erosion appeared minimal along the Michigan shore between Marquette and Big Bay. The coastline was forested, with a narrow beach. Generally, forests extended to the high water line with no evidence of severe shore erosion.

Sand dunes of the Grand Sable Banks near Grand Marais, Michigan, are subject to blowouts (Fig. 2) and wind erosion. The shore at Whitefish Point, Michigan, is relatively flat and is eroding. Rock was exposed in many areas, but where vegetation existed, it retained small mounds of sand; this area showed some of the most successful examples of sand retention by vegetation.

No emergent hydrophytes were observed on the Lake Superior shores.

Extensive beach areas north of Port Wing, Wisconsin, are stabilized by the terrestrial codominants beach-pea *(Lathyrus maritimus)* and wild rye *(Elymus mollis)*. A low topographic relief enhanced land stabilization by both rhizomatous perennials. Dense rhizomatous mats of bluejoint *(Calamagrostis canadensis)*, prairie sandreed *(Calamovilfa longifolia)*, brome grass *(Bromus kalmii)*, and rush *(Juncus balticus)* were observed at Cornucopia, Wisconsin. These heterogeneous stands close to the wave-shore interface provided excellent control against surface runoff.

Eleven miles west of Munising, Michigan, is a sandy shore stabilized by wild rye and sand cherry *(Prunus pumila)*. Invasion of the secondary colonizer, sand cherry, is successfully stabilizing the soil (Fig. 3). Active sand dune blowouts, stable sand dunes, and successional plant establishment were found at Grand Marais State Park, Michigan. Pioneer sand stabilizer was again wild rye. The lee side of active dunes was colonized by the herbaceous pioneer tansy *(Tanacetum huronense)* and the secondary colonizers sand cherry and heart-leaved willow *(Salix cordata)*. Tertiary species were limited to balsam poplar *(Populus balsamifera)*. At Whitefish Point, Michigan, abrasion by blowing sand limited vegetative vitality and diversity, although the low-habit false heather *(Hudsonia tomentosa)*, along with scouring rush *(Equisetum hyemale)* and wild rye, were vigorous enough to impede the wind and accumulate appreciable sand mounds.

Some bank erosion along the Lake Superior shore was caused by seepage (Fig. 4) and wave scouring (Fig. 5). Only one structure was noted, riprap to abate bank erosion near the State highway at Herbster, Wisconsin. The treatment appeared successful; the bank was stabilized, with vegetation well established between the riprap and road to prevent erosion due to surface runoff.

2. Lake Michigan.

Kewaunee County shores south of Kewaunee, Wisconsin, were high, near-vertical bluffs of glacial till with exposed sand and gravel lenses. During wet periods, the lenses become water-saturated and seepage along

Figure 2. Sand blowout caused by wind erosion.

Figure 3. A secondary colonizer, sand cherry, invading a sand dune moderately stabilized by wild rye.

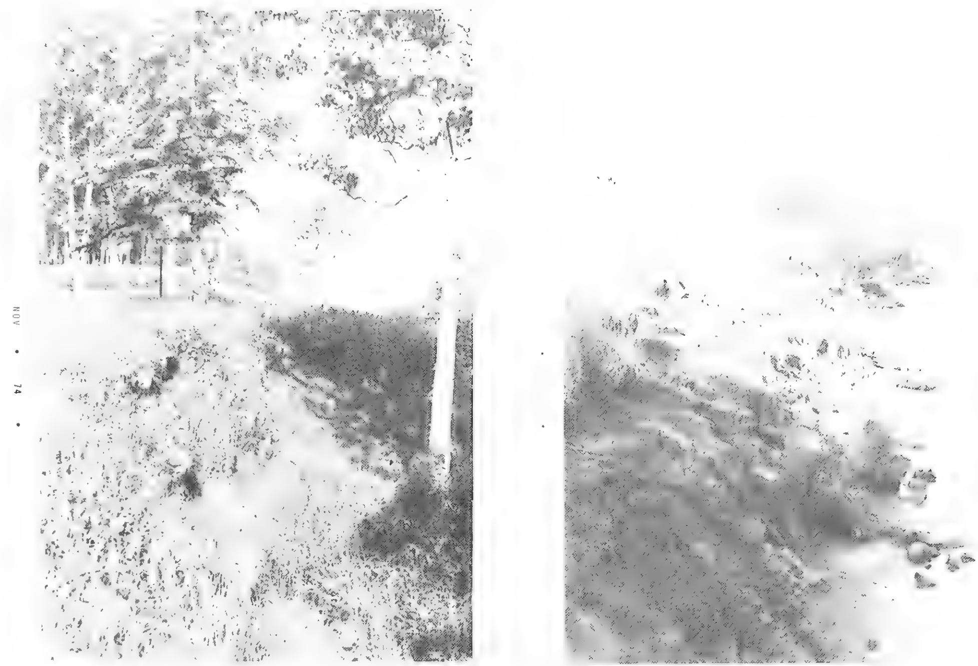


Figure 4. Bank erosion caused by seepage high above the water level (left). Wave action on toe of slope (right) accelerates soil movement down the bank.

Figure 5. Wave scouring causes undercutting and bank recession with loss of vegetation.

the bluff causes slumping of the soil and, at times, large landslides.

Shore conditions of Lake Michigan from Milwaukee, Wisconsin, to Muskegon, Michigan, varied from sloping beaches to severely eroding bluffs. The shoreline of Cecil Bay was not severely eroding; the bay formed a protected area with a relatively flat bottom for a considerable distance from shore.

Two emergent hydrophytes, great bulrush *(Scirpus acutus)* and spike rush *(Eleocharis palustris)* were observed at Cecil Bay, Michigan.

Vigorous stands of wild rye were present at the public beach at Kewaunee, Wisconsin, despite public land use pressures. At Illinois Beach State Park, diverse plant species enhanced sand accumulation. The pioneer wild rye and the secondary invaders, creeping cedar *(Juniperus horizontalis)*, false Solomon's seal *(Smilacina stellata)*, sandbar-willow *(Salix interior)*, pepper-grass *(Lepidium virginicum)*, wild rose *(Rosa blanda)*, forest-grape *(Vitis riparia)*, sand cherry, and bearberry *(Arctostaphylos uva-ursi)* were well established. Wild rye, an excellent sand binding grass, was present also at Porter, Indiana.

Steep, unstable sandy bluffs are a problem at New Buffalo, Michigan, but the sand cherry established on the more gentle cap has increased slope stability, thereby retarding the sloughing process. High water toe lines were stabilized by forest-grape and red osier dogwood *(Cornus stolonifera)* at Union Pier, Michigan. Stabilized dunes were noted at Warren Dunes State Park, Michigan. There, the dominant rhizomatous grass, prairie sandreed, provided a wind impediment resulting in sand accumulation and dune stabilization.

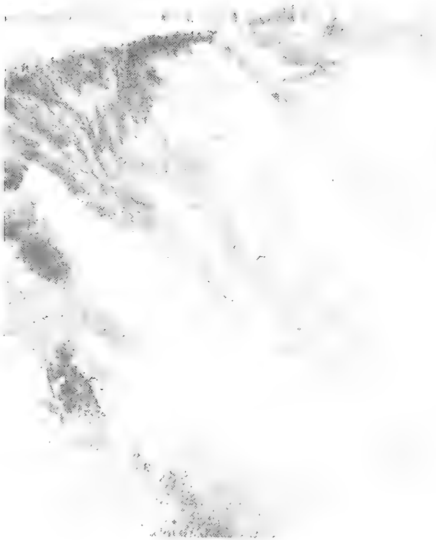
The Soil Conservation Service at Kewaunee, Wisconsin, has successfully stabilized shores by dewatering the glacial till, sloping the face of the bluffs, and seeding the reshaped slopes (Fig. 6). In this case, dewatering is the key factor and is essential to control erosion caused by seepage.

At the Kenilworth, Illinois, Public Water Works, a concrete seawall and groin have been built (Fig. 7). A private residential beach fronted the seawall, but the recent rise in water level has reduced the beach to a small area adjacent to the groin. This seawall has successfully controlled bank erosion.

About 4.5 miles south of Grand Haven, Michigan, a high sandbank overlies a firm clay base; rainfall rapidly eroded the unprotected sand, and gullies developed in the shore. Public access will influence what type of vegetation is used here.

3. Lake Huron.

The northern shores of Lake Huron, from its junction with Interstate Highway 75 to De Tour Village, Michigan, (and adjacent to State



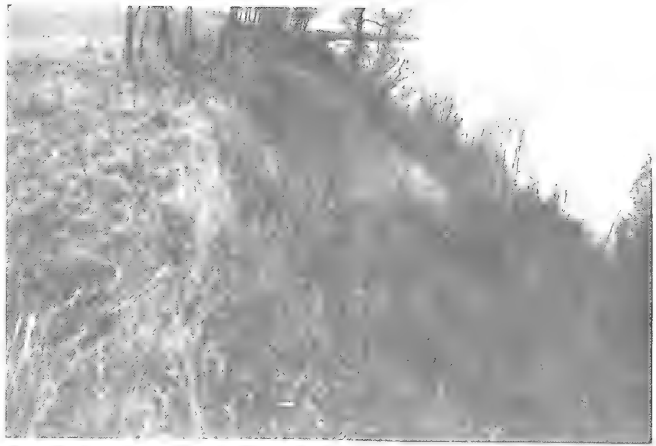


Figure 6. Lake Michigan bank erosion caused by seepage through sand and gravel layers in the glacial till (left). Dewatering, bank reshaping, and seeding to prevent erosion by runoff has stabilized bank recession (above). (Courtesy of Soil Conservation Service.)

Figure 7. A seawall at Kenilworth, Illinois, has successfully stabilized the bank.

Highway 134), is about 43 miles long. The shore consists of low plains and some outcrops of limestone and dolomite. None of the sites inspected had severely eroding shorelines.

A second survey was made along U.S. Highway 23 from Mackinaw City, Michigan, to Hammond Bay, where the shore is potentially erodible even though stony. Although the banks appeared to be easily erodible, there was little evidence of severe erosion, and grasses and broadleaved plants were observed in the sandy reaches.

A gently sloping shore 3.5 miles east of State Route 134 and the Interstate 75 interchange provided suitable habitat for bluejoint, great bulrush, and rush (Fig. 8). Although bluejoint and rush are flood-tolerant, they are not important species for wave attenuation.

About 38 miles east of the State Route 134-Interstate 75 interchange, pioneer, secondary, and tertiary terrestrial species were observed. Rhizomatous, herbaceous pioneers included wild rye and bluejoint. Secondary species included creeping cedar, false Solomon's seal, sand cherry, and bearberry. The invading arborescent tertiary species was balsam fir *(Abies balsamea)*. Pioneer species such as silver-weed *(Potentilla anserina)* closely associated with the land-water interface were observed at 6.7 miles northwest of Huron Beach, Michigan, on U.S. Route 23. Other sampling points along Lake Huron were at 5.9 and 2.8 miles northwest of Huron Beach, Michigan, on U.S. Route 23. Plants observed at the former site included wheat grass *(Agropyron dasystachyum)*, wild rye, false Solomon's seal, sand cherry, beach-pea, and red osier dogwood; the latter site contained wild rye, heart-leaved willow, sand cherry, and bearberry.

4. Lake Erie.

Severe bank erosion was evident along all of the Lake Erie shore examined. The frequent wave attack on the shore prevents establishment of submergent and emergent hydrophytes that might be used for erosion control.

Terrestrial plants observed along the Lake Erie shore were cottonwood *(Populus deltoides)* and sandbar willow near Sterling State Park, Michigan, and cottonwood and wild rye at Presque Isle State Park near Erie, Pennsylvania. None of these plants was exposed to waves.

A breakwater jetty at Ashtabula, Ohio, produced a stilling effect between the structure and the shore, providing habitat for reed (Fig. 9).

5. Lake Ontario.

Wave action and erosion along Lake Ontario shores were as severe as along Lake Erie shores; no erosion-controlling hydrophytic or terrestrial plants were observed.

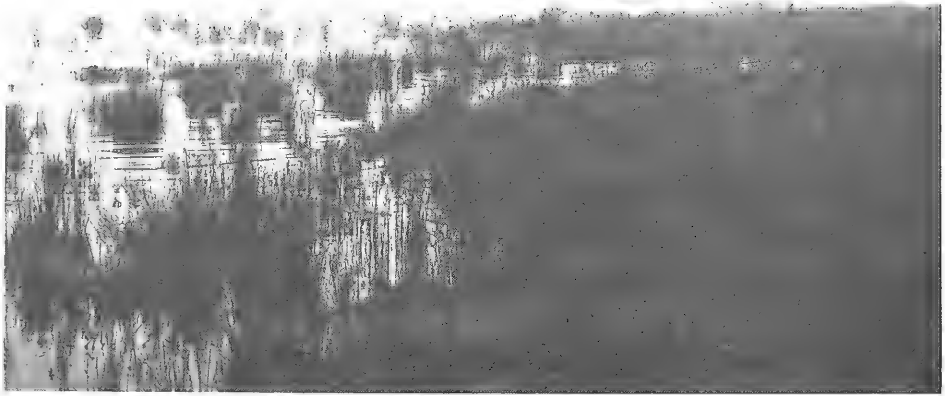


Figure Gently sloping shoreline (Lake Michigan) and relatively quiet waters provide a suitable habitat for bluejoint, great bulrush, and rush.

Figure 9. Protective structure creating pool favorable for growth of reed.

At Hamlin Beach State Park, New York, a high sandbank was graded to a slope of 1:12 (1 unit vertical to 12 units horizontal) and seeded with a grass mixture to stabilize the sand against erosion (Fig. 10). Before reshaping, the sandbank was being eroded by waves; the shore has now stabilized and is a heavily used recreational area.

IV. RESULTS AND DISCUSSION

1. Literature Review.

The most promising information from the literature on use of vegetation for erosion control was from Edminster (1949), who suggests plant establishment to control erosion of streambanks. Mulch techniques to temporarily control erosion and to help establish vegetation, with definite guidelines for establishing and maintaining vegetation, are published by the Soil Conservation Service (1966, 1969).

A study of the erosion problem of Berrien County, Michigan, identified problem localities and factors contributing to the problems and suggested corrective action (U.S. Congress, 1958). A more recent study for Lakes Michigan and Huron was made by the Michigan Water Resources Commission (Brater and Seibel, 1973). That engineering study determined the severity of erosion and the rate of bluff recession at selected locations. The Ohio Department of Natural Resources (1961) performed a similar study for the Ohio shoreline along Lake Erie; the U.S. Army Engineer Division, North Central (1971), conducted a general study of erosion on all the Great Lakes. The U.S. Army, Corps of Engineers (1971a) established shore management guidelines and also published guidelines for shore protection (1971b).

Carter (1973) described and evaluated structures and natural features relative to erosion of the Lake Erie shoreline. The State of Minnesota published two reports on shore management (Minnesota Department of Natural Resources, 1971a, b). A report on low cost shore protection for the Great Lakes was published by the University of Michigan (1959), and, although costs have increased, construction methods remain the same.

Literature sources (Lamson and Scribner, 1894; Cowles, 1899; Weaver and Clements, 1938; Soil Conservation Service, 1974) provide lists of plant species potentially useful for erosion control. The erosion abatement potential of these is usually further enhanced if several species are mixed within an area; many of the plants occur naturally in association with one or two other species. Colonizing category, morphological adaptations, seasonal occurrence, and growth form of plant species derived from literature sources are listed in Table 3.

2. Field Survey.

a. Emergent and Submergent Vegetation. The coastline of the Great

Figure 10. Landscaped beach area and parking lot developed by reforming a high eroding sandbank.

Table 3. Characteristics of plants identified during literature review that are effective for erosion abatement along the Great Lakes shoreline.

Common Name	Scientific Name	Characteristics
Wheat grass	*Agropyron dasystachyum*	Pioneer, rhizomatous, herbaceous perennial occurring on dunes and droughty soil; traps sand, forms dunes
Quack grass	*Agropyron repens*	Pioneer, rhizomatous, herbaceous perennial occurring along gravelly coasts; binds slopes
European beachgrass	*Ammophila arenaria*	Pioneer, rhizomatous, herbaceous perennial occurring along the coast; traps sand, forms dunes
American beachgrass	*Ammophila breviligulata*	Pioneer, rhizomatous, herbaceous perennial occurring on dunes
Little bluestem	*Andropogon scoparius*	Pioneer, rhizomatous, herbaceous perennial occurring in open fields and woods
Bearberry	*Arctostaphylos uva-ursi*	Secondary, perennial woody shrub occurring on sand and exposed rock; forms dunes
Smooth brome grass	*Bromus inermis*	Pioneer, rhizomatous-stoloniferous, herbaceous perennial occurring along roadsides and fields; forms turf, stabilizes slopes
Prairie sandreed	*Calamovilfa longifolia*	Pioneer, rhizomatous, herbaceous perennial occurring on sand, often with European beachgrass; traps sand
Buttonbush	*Cephalanthus occidentalis*	Secondary, perennial woody shrub occurring in swamps and stream banks; slowly accumulates sand and creates dunes
Inland sea oats	*Chasmanthium latifolium*	Pioneer, rhizomatous, herbaceous perennial occurring in moist woods and low thickets; binds streams and river banks
Indian reed grass	*Cinna arundinacea*	Pioneer, rhizomatous, herbaceous perennial occurring in moist woods and shaded swamps; binds streams and river banks
Red osier dogwood	*Cornus stolonifera*	Secondary, stoloniferous, perennial woody shrub occurring in thickets and on shores; forms dunes
Persimmon	*Diospyros virginiana*	Tertiary, perennial tree occurring on abandoned fields; effective for dune stabilization
Autumn olive	*Elaeagnus umbellata*	Secondary, perennial woody shrub occurring in thickets and on roadside banks; effective for dune stabilization
Sea lyme grass, circa 1894 (Wild rye)	*Elymus arenarius* (*E. mollis*)	Pioneer, rhizomatous, herbaceous perennial occurring on sandy beaches; often grows with European beachgrass
Wild rye	*Elymus canadensis*	Pioneer, rhizomatous, herbaceous perennial occurring on sandy, gravelly, rocky soil; stabilizes sandy surfaces
Black huckleberry	*Gaylussacia baccata*	Secondary, perennial woody shrub occurring in woods, thickets, and clearings; often occurs with junipers to form dunes
Rush	*Juncus balticus*	Pioneer, rhizomatous, herbaceous perennial occurring on sandy, brackish to freshwater shores; forms small dunes
Juniper	*Juniperus communis*	Secondary, perennial woody shrub occurring on droughty soils; forms dunes
Knot-root grass	*Muhlenbergia mexicana*	Pioneer, rhizomatous, herbaceous perennial occurring along shores, thickets, damp clearings, and sandy soils
No common name	*Paronychia jamesii*	Secondary, perennial woody shrub occurring on rock slopes, breaks, dunes, and clay soils; adapted to gravelly soils
Reed canary grass	*Phalaris arundinacea*	Pioneer, rhizomatous, herbaceous perennial occurring along shores, swales, and meadows; controls stream bank erosion
Common reed grass	*Phragmites australis*	Pioneer, rhizomatous, herbaceous perennial; similar to reed canary grass
Japanese black pine	*Pinus thungergii*	Tertiary, perennial tree; horticultural; effective for dune stabilization
Water smartweed	*Polygonum amphibium*	Secondary, rhizomatous, herbaceous perennial occurring in meadows, swamps, shores, and ditches; traps sand and forms dunes
Balsam poplar	*Populus balsamifera*	Tertiary, perennial tree occurring along river banks; forms dunes
Silver-weed	*Potentilla anserina*	Pioneer, stoloniferous, herbaceous perennial occurring on sandy shores and banks; traps sand, forms dunes
Beach plum	*Prunus maritima*	Secondary, perennial woody shrub occurring on coastal sandy soils; effective for sand dune stabilization
Sand cherry	*Prunus pumila*	Secondary, perennial woody shrub occurring on dunes, sand, and calcareous, rocky shores; dune builder
'Arnot' bristly locus	*Robinia fertilis* (*R. hispida*)	Tertiary, perennial tree occurring in dry woods, thickets, and on slopes; effective for sand dune stabilization
Heart-leaved willow	*Salix cordata*	Secondary, perennial woody shrub occurring on gravelly, sandy shores, beaches, and dunes; dune builder
Dune willow	*Salix glaucophylloides*	Secondary, perennial woody shrub occurring on gravelly shores, thickets, and mainly on calcareous soils; dune builder
Cordgrass	*Spartina pectinata*	Pioneer, rhizomatous, herbaceous perennial occurring along shores, in swamps and wet prairies; sand stabilizer
Forest-grape	*Vitis vulpina*	Secondary, perennial woody shrub occurring along river banks, in bottom-lands and thickets; checks advance of sand on protected sand dune slopes

Lakes is mostly abrupt, although there are some protected areas on the northern shore of Lake Huron and also at Cecil Bay west of Mackinaw City, Michigan. These protected areas have shores conducive to aquatic plant growth but the gentle action of the water there has resulted in no erosion hazard. Thus, areas where aquatic plants will survive are not areas of primary concern relative to erosion. Where erosion and shoreline recession is a major problem, the coastline conditions and wave action prevent growth of hydrophytes, especially submergent plants.

Wave action along the shores of Lakes Superior, Erie, and Ontario prevents establishment of any hydrophytic plants that might have erosion-controlling properties.

Lakes Michigan and Huron have some protected bays and inlets suitable for emergent and submergent vegetation. Plants observed there were herbaceous terete species. Other plants, such as great bulrush, spike rush, and bulrush, will establish there if the shore is gently sloping.

A gently sloping shore on Lake Huron 3.5 miles east of the State Route 134 and Interstate 75 interchange provided habitat for bluejoint, great bulrush, and rush. These plants will not withstand harsh wave action; they cannot be considered suitable for wave attenuation.

One of the few excellent habitats for emergent hydrophytes was found on Lake Michigan at Cecil Bay, where great bulrush and spike rush were very effective in wave dampening.

b. Terrestrial Vegetation and Shore Alterations. The ability of a shoreline to resist erosion, or its resiliency to water dynamics, depends upon the composition of material making up the shore front and the adaptability of its vegetation. The erosion resistance of the Great Lakes shores diminishes from the rock bluffs and rocky shorelines of Lakes Superior and Huron, to the sandy beaches of Lake Michigan, to the silty-clay bluffs along Lake Erie. Similarly, the erosion abatement potential of the terrestrial vegetation varies from location to location along the Great Lakes shores.

Qualitative evaluations of the erosion-controlling potential of each vegetative species were obtained *in situ* using the scorecard (Table 1). Species found during the field survey are listed in Table 4, and an average site index of the observed species is given in Table 5. Vegetative species classified as excellent for erosion abatement in their ecologically adapted areas included balsam firm, juniper, creeping cedar, brome grass, reed *(Phragmites communis)*, wild rye, bluejoint, prairie sandreed, spike rush, great bulrush, rush, balsam poplar, cottonwood, speckled alder *(Alnus rugosa)*, silver-weed, beach-pea, false heather, red osier dogwood, and bearberry. The remaining species classified as good include scouring rush, wheat grass, wild rye, reed canary grass *(Phalaris arundinacea)*, bulrush *(Scirpus americanus)*, false Solomon's seal, sandbar willow, heart-leaved willow,

Table 4. Characteristics of plants identified during field survey that are effective for erosion abatement along the Great Lakes shoreline.

Common name	Scientific name	Characteristics
Balsam fir	*Abies balsamea*	Tertiary tree, perennial occurring in shoreline woods
Wheat grass	*Agropyron dasystachyum*	Pioneer, rhizomatous, herbaceous perennial occurring in droughty soils
Speckled alder	*Alnus rugosa*	Tertiary tree, perennial occurring in depressions, swamps, and along stream banks
Bearberry	*Arctostaphylos uva-ursi*	Secondary, perennial woody shrub, occurring on rock outcrops and in sand
Brome grass	*Bromus kalmii*	Pioneer, rhizomatous, herbaceous perennial occurring in calcareous, open soils, and thickets
Bluejoint	*Calamagrostis canadensis*	Pioneer, rhizomatous, herbaceous perennial occurring in meadows, bogs, and wet thickets
Prairie sandreed	*Calamovilfa longifolia*	Pioneer, rhizomatous, herbaceous perennial occurring in sand
Red osier dogwood	*Cornus stolonifer*	Secondary, stoloniferous perennial woody shrub, occurring in thickets and shore areas
Spike rush	*Eleocharis palustris (E. smallii)*	Pioneer, rhizomatous, herbaceous perennial occurring in marshes, ponds, and on stream banks
Wild rye	*Elymus arenarius (E. mollis)*	Pioneer, rhizomatous, herbaceous perennial occurring in droughty, sandy, and rocky soil
Wild rye	*Elymus mollis*	Pioneer, rhizomatous, herbaceous perennial occurring in sandy areas and beaches
Scouring rush	*Equisetum fluviatile*	Pioneer, rhizomatous, herbaceous perennial occurring in shallow water and wet thickets
Scouring rush	*Equisetum hyemale*	Pioneer, rhizomatous, herbaceous perennial occurring on sand or clay shores
False heather	*Hudsonia tomentosa*	Pioneer, perennial woody shrub occurring on dunes and sand-blows
Rush	*Juncus balticus*	Pioneer, rhizomatous, herbaceous perennial occurring on brackish to freshwater shores
Juniper	*Juniperus communis*	Secondary, perennial woody shrub occurring in droughty soils
Creeping cedar	*Juniperus horizontalis*	Secondary, perennial woody shrub occurring on rocky or sandy banks
Beach-pea	*Lathyrus maritimus (L. Japonicus)*	Pioneer, rhizomatous, herbaceous perennial occurring on sandy, gravelly shores
Pepper-grass	*Lepidium virginicum*	Secondary, herbaceous annual or biennial occurring in droughty soils
Reed canary grass	*Phalaris arundinacea*	Pioneer, rhizomatous, herbaceous perennial occurring on shores and in swales and meadows
Reed	*Phragmites communis*	Pioneer, rhizomatous-stoloniferous, herbaceous perennial occurring in fresh to alkaline marshes, ditches, and depressions
Balsam poplar	*Populus balsamifera*	Tertiary, perennial tree occurring on river banks
Cottonwood	*Populus deltoides*	Tertiary, perennial tree occurring on river banks
Silver-weed	*Potentilla anserina*	Pioneer, stoloniferous, herbaceous perennial occurring on sandy, gravelly shores
Sand cherry	*Prunus pumila*	Secondary, perennial woody shrub occurring on sandy, gravelly shores
Wild rose	*Rosa blanda*	Secondary, rhizomatous, perennial woody shrub occurring on rocky slopes
Heart-leaved willow	*Salix cordata*	Secondary, perennial woody shrub occurring on sandy, gravelly shores
Sandbar-willow	*Salix interior*	Secondary, stoloniferous, perennial woody shrub occurring in alluvial soils
Great bulrush	*Scirpus acutus*	Pioneer, rhizomatous, perennial woody shrub occurring in marshes and on shores
Bulrush	*Scirpus americanus*	Pioneer, rhizomatous, herbaceous perennial occurring on freshwater, brackish, or saline shores
False Solomon's seal	*Smilacina stellata*	Secondary, rhizomatous-stoloniferous, herbaceous perennial occurring on gravelly or alluvial shores
Tansy	*Tanacetum huronense*	Pioneer, stoloniferous, herbaceous perennial occurring in sands and gravels
Forest-grape	*Vitis riparia*	Secondary, perennial woody vine, occurring on river banks and in thickets

Table 5. Plant species with good to excellent potential for erosion abatement at sampling points along the Great Lakes shoreline.

Family / Common name / Scientific Name	Sampling locations[1]																							Average Site Index[2]
	2	4	5	6	8	9	10	11	12	15	16	17	18	20	21	22	23	24	25	26	27	37	39	
Equisetaceae																								
Scouring rush																								
Equisetum fluviatile															27									27.0
Equisetum hyemale							20																	20.0
Pinaceae																								
Balsam fir																								
Abies balsamea																14								14.0
Cypressaceae																								
Juniper																								
Juniperus communis																12								12.0
Creeping cedar																								
Juniperus horizontalis									7							14								10.5
Gramineae																								
Brome grass																								
Bromus kalmii			12																					12.0
Reed																								
Phragmites communis															8							12		10.0
Wheat grass																								
Agropyron dasystachyum																			21					21.0
Wild rye																								
Elymus mollis	10				12	17	10	8		8						19			20	20		10		13.4
Elymus canadensis						22	24		23															23.0
Bluejoint																								
Calamagrostis canadensis			8													20	21							16.3
Prairie sandreed																								
Calamovilfa longifolia			9									11												10.0
Reed canary grass																								
Phalaris arundinacea		19																						19.0
Rosaceae																								
Silver-weed																								
Potentilla anserina																		10						10.0
Wild rose																								
Rosa blanda									25															25.0
Sand cherry																								
Prunus pumila					20		23		23		16					19			17	25				20.4
Fabaceae																								
Beach-pea																								
Lathyrus maritimus	15						24												10					16.3
Vitaceae																								
Forest-grape																								
Vitis riparia									16			22		24										20.7
Cistaceae																								
False heather																								
Hudsonia tomentosa							17																	17.0
Cornaceae																								
Red osier dogwood																								
Cornus stolonifera				12								17		21					16					16.5
Ericaceae																								
Bearberry																								
Arctostaphylos uva-ursi							22		7							16				22				16.8
Compositae																								
Tansy																								
Tanacetum huronense						27																		27.0
Cyperaceae																								
Spike rush																								
Eleocharis palustris															14									14.0
Bulrush																								
Scirpus americanus															23									23.0
Great bulrush																								
Scirpus acutus															17		17							17.0
Juncaceae																								
Rush																								
Juncus balticus			9														20	10						13.0
Liliaceae																								
False Solomon's seal																								
Smilacina stellata									28							24			23					25.0
Salicaceae																								
Balsam-poplar																								
Populus balsamifera						15																		15.0
Cottonwood																								
Populus deltoides																					22		12	17.0
Sandbar-willow																								
Salix interior									26					24							20			23.3
Heart-leaved willow																								
Salix cordata						27														21				23.5
Betulaceae																								
Speckled alder																								
Alnus rugosa				15																				15.0
Cruciferae																								
Pepper-grass																								
Lepidium virginicum									28															28.0

1. Sampling locations are indicated on Figure 1.

2. This number is the average of scores for that individual species from all locations where it was encountered. Interpretation of indexes are: Excellent 7 to 18; Good 19 to 30 (see also Table 1).

pepper-grass, wild rose, sand cherry, forest-grape, and tansy. Most plants were observed in heterogeneous stands with no pronounced dominance by an individual species.

Species most effective as sand accumulators have a low-growth profile with minor vertical stratification. Species exemplifying this growth habit include most grasses, juniper, creeping cedar, rush, false Solomon's seal, silver-weed, beach-pea, bearberry, and tansy.

Plants common to both literature and vegetative surveys were: wild rye, prairie sandreed, reed canary grass, wheat-grass, heart-leaved willow, sand cherry, red osier dogwood, balsam poplar, rush, bearberry, juniper *(Juniperus communis)*, and silver-weed.

Land alteration has proved essential for controlling shore and bank erosion in many areas of the Great Lakes. Near Kewaunee, Wisconsin, for example, seepage contributes to bank failure along Lake Michigan. The Soil Conservation Service has successfully installed a deep tile line to intercept seepage and conduct the underground water to Lake Michigan. The banks were reshaped to an approximate slope of 2:1 and the soil was seeded with a mixture of crown vetch and fescue to control surface run-off. Similar dewatering has been effective in urban and rural areas. The work is costly, especially on high banks. In time, if seeding has successfully stabilized soil on the banks, native plant species invade and become established along with planted species.

Clay with glacial overburden containing sand and gravel lenses can be effectively dewatered provided there is a discharge outlet to dispose of the intercepted surface and seepage water. Because of high cost, dewatering must be carefully evaluated.

The critical factor for success in this type of stabilization is effective dewatering of the soil and establishing of vegetative cover to prevent surface erosion.

An example of a Lake Michigan shore modification is shown in Figure 11. The site was in Racine County about 3 miles north of Racine, Wisconsin. Rock was used for shoreline protection to minimize erosion of the embankment. The rough steep bank was graded to a more gentle slope and was seeded to control surface erosion. This shore front modification requires a soil that is not subject to seepage so severe that it causes bank failure. Loam soil is best for this type of reclamation. The best vegetative growth is obtained by topdressing with fertilizer and irrigating. Where a specific type of vegetation is desired, weed control may also be required. This shore front renovation requires constant management to maintain a turf appearance.

Reforming and vegetating the beach at Hamlin State Park, New York, on Lake Ontario (Fig. 10) was successful. A high sandbank was reshaped to a 1:12 slope to reduce erosion by dissipating wave energy. The beach and its adjacent recreational area were vegetated to control surface erosion. Since this shoreline modification was for recreation,

Figure 11. Reformation of rough bank (above) and landscaping of shoreline (below). (Courtesy of Soil Conservation Service.)

a species able to withstand frequent mowing was used. This type of vegetation requires constant management. Unfortunately, not all soils are adapted for this type of erosion control. Coarse sands are well adapted, while silt and clay soils are not; their very fine particles are easily moved by water.

c. Vegetation in Combination with Structures. During the field survey, three structures were observed that were successful, in combination with vegetation, in controlling shoreline erosion. The structures were located on Lakes Superior, Michigan, and Erie, and were of three different types: riprap, seawall with groin, and jetty.

Near the state highway at Herbster, Wisconsin, on Lake Superior, riprap was installed to abate bank erosion. The riprap has stabilized the bank against wave action; a well-established vegetative cover has decreased the runoff rate.

Another structure that is successful in controlling bank erosion is a concrete seawall and groin at the Kenilworth, Illinois, Public Water Works on Lake Michigan (Fig. 7). Lake level increases here have greatly reduced a private beach that fronted the seawall, but the wall is very effective in dissipating wave energy. The dense and well-established vegetation behind the wall successfully prevents surface runoff erosion on the bank.

On Lake Erie, at Ashtabula, Ohio, a jetty (Fig. 9) has effectively dampened wave action so that a pool has formed between the shore and the structure itself. The quieter pool area is a desirable habitat for reed, which in turn provides aquatic habitat and enhances the aesthetic quality of the shore.

V. SUMMARY AND CONCLUSIONS

Attempts to establish vegetation on the shores of the Great Lakes, particularly Lakes Erie and Ontario, for erosion abatement are not expected to be successful without structural wave dampening, and often, land reforming. After wave force has been reduced and the shoreline stabilized by use of structural methods, vegetation can be established to further stabilize the soil, and thus reduce surface erosion resulting from runoff. If vegetation is to be established to dampen waves and to limit inland wave penetration, some reforming to develop a gradual slope of the foreshore is desirable and may be feasible in places.

Establishment and maintenance of an effective vegetative cover on sandy areas will require fertilizing and irrigating, and continuous maintenance will be necessary. The vegetation selected must be compatible with the land use, particularly if the area has public access. Before any attempt is made to stabilize the sand with vegetation, the effect of seepage must be evaluated to determine if dewatering is needed for a firm sand-clay interface.

The principal use of vegetation on the Great Lakes shores is to abate surface erosion caused by runoff or wind. Plants found frequently during the survey are false Solomon's seal, wild rye, and sand cherry. Information on surface erosion and the various techniques for its control (dewatering, slope grading, sand stabilization) are available from the Soil Conservation Service or the County Agriculture Extension Agent.

Further research on use of aquatic plants for erosion abatement on the Great Lakes shores is not recommended because open shoreline conditions are not favorable for the growth and maintenance of introduced submergent and emergent plants.

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1. Shore erosion. 2. Great Lakes. 3. Shoreline changes. 4. Plants. 5. Coastal structures. I. Title. II. Ludwig, J.D., joint author. (Series) (Contract)

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1. Shore erosion. 2. Great Lakes. 3. Shoreline changes. 4. Plants. 5. Coastal structures. I. Title. II. Ludwig, J.D., joint author. (Series) (Contract)

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